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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division

PROTECTING STORED SEED FROM INSECT ATTACK [1]

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The protection of seed from insect attack is of great importance to the seedsman faced with the problem of preserving bulk seed until it can be packaged and surplus seed that must be carried over from one season to another. Stored seeds make an ideal diet for a large group of insects known popularly as stored-product insects. These insects have adapted themselves to living on foods low in moisture content. The germ of the seed, with its high food value, is particularly attractive to these insects, and is often the first part attacked by such species as the Indian-meal moth (*Plodia interpunctella* (Hbn.)), the cadelle (*Tenebroides mauritanicus* (L.)), and the flat grain beetle (*Laemophloeus pusillus* (Schönh)).

Information on the protection of seed from insects is by no means complete. However, to meet the demand for information on this subject, the best information available at this time is presented.

Factors Affecting Development of Grain Insects

Seed should be kept in a dormant condition if its viability is to be preserved. High moisture content and high temperature speed up the life processes of seed. For this reason the fundamental requirement for the preservation of seed is low moisture. Low temperature is also helpful but not indispensable.

The factors that speed up the life processes of seed similarly affect the seed-infesting insects. Within certain limits, the higher the moisture content of the seed and the higher the temperature, the faster these insects reproduce. Seed that is cool, dry, and free from dockage (dust or broken kernels) is unfavorable for insect development.

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[1] Revision of E-677, issued by the former Bureau of Entomology and Plant Quarantine, December 1945.

Agriculture-Washington July 1955

The rice weevil (Sitophilus oryza (L.)) and the granary weevil (S. granaria (L.)), the most serious pests of stored grains, cannot breed in seed with a moisture content of 8 percent or less, and they soon die if restricted to such seed for food. Mites, which are not true insects but are usually classed with this group of seed pests, require food with a rather high moisture content; they are not troublesome in seed unless the moisture content is above 12 percent. Moths such as the Indian-meal moth, the Mediterranean flour moth (Ephestia kuehniella Zell.), and the almond moth (E. cautella (Walker)), insects of the bran beetle type such as the saw-toothed beetle (Oryzaephilus surinamensis (L.)), and the flour beetles (Tribolium spp.) are capable of breeding in seed almost devoid of moisture. Flour beetles are not troublesome in dry clean seed if free from broken kernels, since the young larvae find it difficult to attack the undamaged seed.

Temperatures above 95° F. are not favorable for the development of most seed-infesting insects. Temperatures below 70° greatly retard their development. A temperature of 65° prevents the reproduction of flour beetles, and 60° is approximately the lowest temperature at which the rice and granary weevils reproduce. Tyroglyphid mites are somewhat more hardy; they are reported to breed in seed kept between 40° and 50°, but only when the seed moisture is above 12 percent. Within the limits shown in figure 1, reproduction of the confused flour beetle (Tribolium confusum Duv.) in wheat increases with the increase in temperature, grain moisture, and amount of dockage.

Moisture Changes in Seed

In the dry climate of the Southwest seeds lose moisture rapidly, and therefore retain their viability longer there than in the South Central and Southeastern States where the relative humidity is high. In the North, where temperatures are lower, a low seed moisture content is not so vital. The relation between seed moisture and the relative humidity of the atmosphere is indicated in table 1.

The estimated maximum proportion of moisture that various kinds of seed may safely contain at different mean temperatures of storage for a year is given in table 2, insect attack not being taken into account.

Sources of Infestation

Most of the insect pests of seed are good fliers, and infestation may occur in the field before harvest. This is particularly true in warm climates, where the insects can survive the winter in the fields. Infestation in the field is not serious with most kinds of seed grown in the North, but is of considerable importance with seed of leguminous crops. These seeds are attacked in the field by bruchid beetles, and most of the species continue to breed after the seed is harvested and placed in storage.

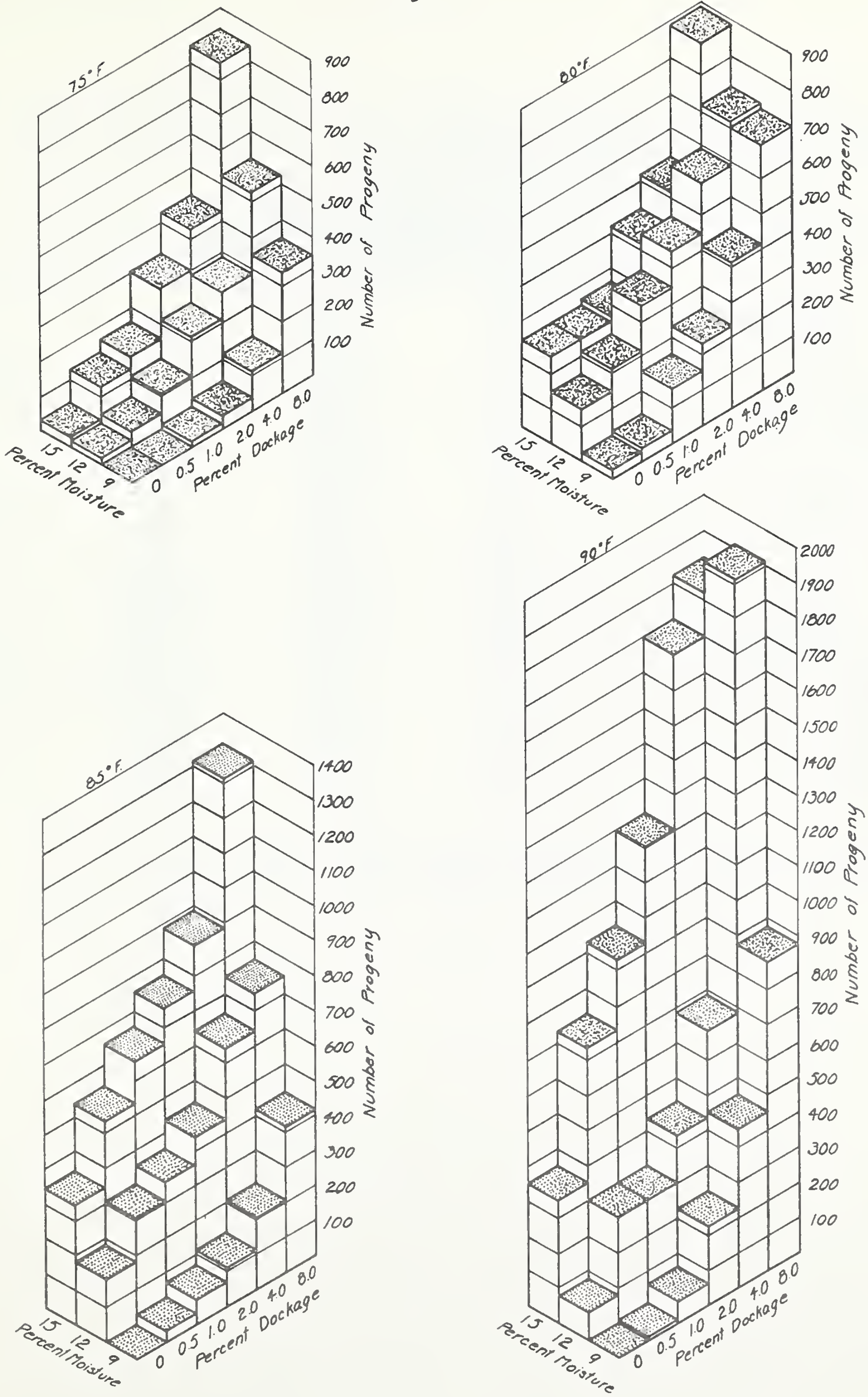

Fig. 1.--Effect of variations in temperature, moisture, and dockage present in wheat seed on the reproduction of 25 confused flour beetles over a 19-week period.

Table 1.--Estimated moisture contents of seed (fresh basis) attained at different relative humidities of air 1/

Kind of seed	Estimated moisture content of seed stored at relative humidity of --			
	45 percent	65 percent	73 percent	80 percent
Bean, kidney	9.0	12.0	14.0	16.0
Bean, lima	9.0	12.0	14.0	15.0
Beet	6.5	10.0	12.5	15.0
Cabbage	6.0	8.0	9.0	10.0
Carrot	7.5	10.0	11.0	12.5
Celery	9.0	11.0	12.0	13.5
Corn, sweet	9.0	11.0	12.5	14.0
Cucumber	7.0	8.5	9.0	10.0
Lettuce	6.0	8.0	9.0	10.0
Okra	10.0	12.0	13.0	14.5
Onion	9.0	11.0	12.0	13.5
Pea, garden	9.0	12.0	13.5	15.5
Peanut (shelled)	4.5	6.0	7.0	8.0
Pepper	7.5	9.5	10.5	12.0
Spinach	10.0	12.0	13.0	14.5
Tomato	8.0	10.0	11.0	12.0
Turnip	6.0	8.0	9.0	10.0
Watermelon	7.5	9.0	10.0	11.0

1/ From U. S. Dept. Agr. Leaflet 220, 8 pp., illus. 1942.

Table 2.--Estimated maximum safe seed moisture contents for storage for 1 year at different mean temperatures (approximate guide only) 1/

Kind of seed	Maximum safe seed moisture content for average temperature of storage indicated		
	40°-50° F. 2/	70° F.	80° F.
	Percent	Percent	Percent
Bean, kidney	15	11	8
Bean, lima	15	11	8
Beet	14	11	9
Cabbage	9	7	5
Carrot	13	9	7
Celery	13	9	7
Corn, sweet	14	10	8
Cucumber	11	9	8
Lettuce	10	7	5
Okra	14	12	10
Onion	11	8	6
Pea, garden	15	13	9
Peanut (shelled)	6	5	3
Pepper	10	9	7
Spinach	13	11	9
Tomato	13	11	9
Turnip	10	8	6
Watermelon	10	8	7

1/ See footnote 1, table 1.

2/ Special precautions are needed when seed is removed to higher temperature.
See Section on cold storage of seed.

Usually, however, infestation occurs after seed is harvested and placed in storage. The insect pests of stored seed are rather general feeders. They breed in feed and grain supplies on farms and in nearly every type of dried food and storage place used by man. Infestation results from storage in bins or warehouses that are not thoroughly clean or that are near sources of infested materials.

Packaged seed that is carried over from one season to another is particularly susceptible to infestation by the Indian-meal moth. This moth, which is one of the most troublesome pests of stored seed, lays its eggs on or near packages. The caterpillars or "worms" that hatch from the eggs are exceedingly small and easily enter the packages at top corners where the gummed flap does not completely seal the package. The caterpillars "web up" the contents and when fully grown cut their way out through the sides of the package.

Preventive measures

Prompt harvesting of seed will greatly reduce the opportunity for field infestation. Seed that has been in the field should be treated as soon as possible after harvest, to prevent further damage to the seed. Seed should be clean and should have as low a moisture content as possible. Storage at temperatures below 70° F. is desirable.

Bin sanitation

After harvest, seed should be dried when necessary, and then stored in clean, insect-free, weather-proof premises. Any nearby sources of insect infestation should be eliminated. Steel bins that are easy to clean and can be tightly calked are best.

Wooden bins should be thoroughly cleaned and the walls and floors treated with a residual spray before they are refilled. This will kill most of the insects that emerge from burrows in the woodwork. Spray around the door frames of steel bins where insects may be concealed.

For spraying bins, use 2.5 percent of DDT, TDE, or methoxychlor by weight as emulsions or water suspensions, or 0.5 percent of pyrethrins or allethrin as emulsions. The sprays should be applied at the rate of about 2 gallons per 1,000 square feet of surface area. They may be applied safely with a power sprayer.

Warehouse sanitation

The warehouse in which bagged seed is stored should be of modern construction, easily cleaned, and tight enough for fumigation. In old, poorly constructed warehouses, every effort should be made to eliminate dead spaces in walls and floors where accumulations of seed offer food and housing for insects.

Double, hollow walls and partitions should be eliminated. If floors are of wood, see that all cracks are filled or kept clean of dust or accumulations of seed. Remove boards and fill openings where floor and walls meet with a good grade of elastic cement. Also fill all cracks around posts and in walls, and paint the walls.

Old wooden floors and badly worn concrete floors are difficult to keep clean. They can be renovated by applying a quick-setting plastic preparation. Light and ventilation should be adequate. Most insect pests of seed seek dark corners in which to hide.

Strict sanitation in the warehouse is imperative. Bagged seed should be stacked on racks or lift platforms, if possible 12 inches from the walls and far enough apart to allow inspection and cleaning. As a preventive measure, spray the floors and walls periodically with a residual spray. Sprays recommended for the treatment of wooden bins can be used for this purpose also.

Fumigation

Fumigation is a rapid and effective method of destroying insect life in stored seed. Unfortunately many fumigants affect the viability of seed, particularly if dosages are excessive, seed moisture is high, temperature high, and exposure period long. The effect of excessive dosages and exposure periods on the viability of seed corn fumigated with chloropicrin is indicated in table 3.

To avoid damage and loss of viability due to fumigation, seed should be fumigated only if the moisture content is less than 12 percent, preferably below 10 percent; seed should be in bags to facilitate aeration; exposures should not exceed 24 hours and preferably should be 12 hours or less; and fumigation temperatures should not be high, preferably 85° F. or less.

In an article on the fumigation of seed corn Richardson[2] states that the following fumigants can be used with relative safety, with respect to their effect on germination, at dosages up to 6 gallons per 1,000 bushels of seed: propylene dichloride, trichloroethylene, carbon disulphide-carbon tetrachloride (1-4 mix), carbon tetrachloride, ethylene dichloride, and the ethylene dichloride-carbon tetrachloride (3-1 mix). He further states that exposure time and removal of fumigant vapor after treatment are important in protecting seed viability. Seed that has been treated with the 1-4 and the 3-1 mixtures should be aerated after from 3 to 5 days. Mixtures containing 5 percent of ethylene dibromide are apparently also safe to use at dosages up to about 6 gallons per 1,000 bushels. He considers acrylonitrile, chloropicrin, and ethylene dibromide highly detrimental to germination.

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[2] Richardson, C. H. Effects of insecticidal fumigants on the germination of seed corn. Jour. Econ. Ent. 44(4):604-608. 1951.

Table 3.--Germination of seed corn of different moisture contents that had been fumigated with different dosages of chloropicrin at 75° F. for various lengths of time

Dosage of fumigant per 1,000 bushels of seed	Period of exposure	Proportion of seed corn that germinated when moisture content was--			
		10 percent	12 percent	14 percent	16 percent
Pounds	Hours	Percent	Percent	Percent	Percent
2	6	74	74	72	68
	12	71	75	69	70
	24	79	77	71	76
	48	74	70	63	65
	72	70	70	63	63
4	6	76	77	70	70
	12	75	71	61	65
	24	71	61	60	58
	48	76	56	55	56
	72	73	60	57	59
6	6	76	76	57	57
	12	70	75	61	58
	24	71	67	56	47
	48	71	59	53	55
	72	72	52	48	48
8	6	73	72	56	59
	12	71	69	54	55
	24	73	60	45	49
	48	71	56	44	46
	72	68	40	45	46
Check (untreated)	-	82	85	80	76

For space fumigation hydrocyanic acid can be used at the rate of 1 pound to 1,000 cubic feet without fear of damage to germination. Methyl bromide is highly effective as a fumigant for bagged seed at a dosage of 1 pound per 1,000 cubic feet of space. It is not used extensively, as many seedsmen have reported damage to the germ from its use. The damage may have been the result of high moisture content of the seed, excessive dosages in certain layers where circulation was insufficient, or the exposures may have been too long.

Precautions. All fumigants are toxic to human beings if breathed in concentrated form. They should be applied only by professional fumigators or employees trained in their use and familiar with the precautions necessary to protect themselves and others in the establishment from exposure to dangerous concentrations. Specific instructions for using fumigants can be obtained by writing to the Stored-Product Insects Section, Agricultural Marketing Service, United States Department of Agriculture, Washington 25, D.C.

Use of Naphthalene and Paradichlorobenzene

Napthalene and paradichlorobenzene crystals have been used extensively for the protection of seed. The recommended dosages vary greatly. A popular dosage is about 1 ounce of the crystals per bushel, although much heavier dosages are sometimes recommended. According to Roark and Nelson, 3/ the maximum weights of naphthalene and of paradichlorobenzene that can exist in vapor form in 1,000 cubic feet of space at 77° F. are 0.04 and 0.5 pound. Therefore, the small dosage recommended is more than sufficient to provide a saturated atmosphere. The crystals mixed with the seed give off vapors that are toxic to insects.

The effect of saturated atmospheres of naphthalene and paradichlorobenzene on the germination of seed corn of different moisture contents was determined by storing seed, together with one-fourth ounce of the crystals, in 1-quart glass jars for various lengths of time. The results of this experiment (table 4) indicate that little injury to germination need be feared from napthalene vapors if the moisture content of the seed is not over 12 percent. Paradichlorobenzene vapors, however, cause considerable damage to germination even in very dry seed. Seed treated with either of these chemicals is unfit for animal feeds, as the chemicals impart an obnoxious odor and taste to the flesh of the animals and to the eggs of poultry.

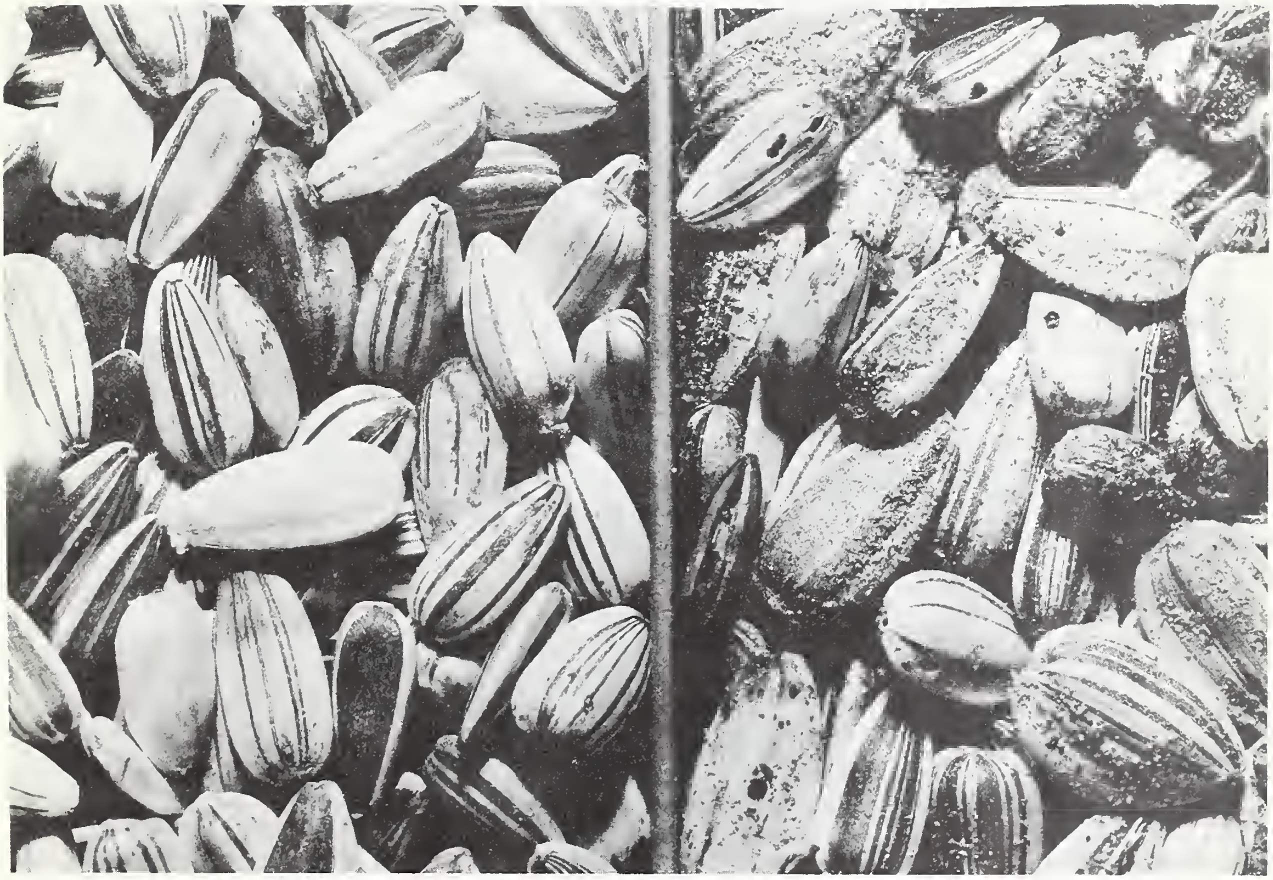
Use of Dusts for Protecting Seed

Of the several methods available for protecting seed from insect attack, mixing seed with a dust provides the most economical and lasting protection (fig. 2). The treatment is simple, and is not hazardous to the workman or injurious to the seed.

3/ Roark, R. C., and Nelson, O. A. Maximum weights of various fumigants which can exist in vapor form in a 1,000 cubic foot fumigation chamber. Jour. Econ. Ent. 22: 381-387. 1929.

Table 4.--Effect of atmospheres saturated with paradichlorobenzene and naphthalene on germination of seed corn containing different amounts of moisture, the seed being exposed for various lengths of time

Chemcial	Period of exposure	Proportion of seed corn that germinated when its moisture content was --			
		10 percent	12 percent	14 percent	16 percent
	Months	Percent	Percent	Percent	Percent
Paradichlorobenzene.	1	86	85	47	0
	2	62	59	19	4
	3	61	38	12	0
	4	49	35	23	0
	5	43	29	9	0
	6	17	10	0	0
	7	35	15	1	0
	8	47	14	0	0
	9	14	14	0	0
	10	0	0	0	0
	11	0	0	0	0
Naphthalene.........	1	90	94	94	93
	2	93	94	91	91
	3	98	97	92	79
	4	95	94	81	51
	5	93	88	64	0
	6	91	79	56	0
	7	95	88	53	0
	8	96	82	32	0
	9	95	75	29	0
	10	95	75	14	0
	11	97	75	19	0
Check (untreated)...	1	93	94	94	91
	2	96	95	96	73
	3	96	97	92	59
	4	97	95	74	21
	5	99	96	85	58
	6	98	96	46	34
	7	97	94	33	5
	8	92	92	15	9
	9	98	96	55	6
	10	98	92	36	0
	11	98	92	36	0



Treated Untreated

Fig. 2.--Two lots of sunflower seed after exposure to insect infestation for 1 year. Seed on left was treated with magnesium oxide and remained undamaged. Untreated seed on right was almost completely destroyed.

Many dusts have been used to protect seed. Some are active insect poisons. Others apparently affect the insects physically rather than chemically. The poisonous dusts may be classified as chemically active, those that appear to have only a physical effect on the insects as chemically inert.

Chemically inert dusts are thought to kill insects by causing breaks in their waterproof fatty covering; their body moisture then evaporates through these breaks. The effectiveness of inert dusts declines as the moisture content of the seed increases over 12 percent.

Inert dusts that have been used successfully for treating seed include finely divided silica gel, rock phosphates, precipitated chalk, magnesium oxide, and aluminum oxide. Dusts with a particle size of 1 micron or less can be used at the rate of 1 part per 1,000 parts by weight or approximately 1 ounce per bushel.

Pyrethrum dusts composed of 0.05 percent of pyrethrum and 0.8 percent of piperonyl butoxide in a talc carrier are excellent for protecting seed stock that are free from insect infestations when treated. They can be applied at a dosage of approximately 1 1/2 to 2 ounces per bushel.

Poisonous dusts are effective regardless of the moisture content of the seed. Because surplus seed stocks often are fed to animals, poisonous dusts have not been popular. DDT, lindane, methoxychlor, and malathion are effective insecticides; however, more work must be done to determine the most effective formulations.

DDT is best used in combination with a carrier such as pyrophyllite or similar chemically inert dust. The carrier increases the volume and therefore insures thorough distribution over the seed. A dust containing 3 percent of DDT is effective when mixed with seed at the rate of one-half ounce per bushel. No damage to seed viability has been observed as a result of treatment with either DDT or magnesium oxide at recommended dosages (table 5). A great many types of seeds may be treated for protection from fungus diseases and insects at the same time by adding a proportion of DDT to the disinfectant dust. Some fungicidal dusts have insecticidal properties but most of them have little effect on insects when used alone.

Dusts may be applied by any method that will insure a uniform coverage. A seed-treating machine is satisfactory for treating bulk seed. Operators applying the dusts should be equipped with adequate respirators.

Slurries and Sprays

DDT can also be made up as a slurry, or thin paste, by adding 2 ounces of 50-percent DDT wettable powder to 1 gallon of water. This amount will treat about 30 bushels of seed.

Seed can also be protected by the use of synergized pyrethrum sprays. Two types of pyrethrum formulations are available commercially. One is in the form of an emulsifiable concentrate to be diluted with water, the other contains a solvent as a carrier and comes ready prepared. Dosage rates are furnished by the manufacturers.

Table 5.--Effect of magnesium oxide and DDT dusts on the germination of wheat of different moisture contents

Dust	Period of exposure	Germination of wheat with indicated seed-moisture content						
		12 percent			14 percent			16 percent
		Percent of dust mixed with seed						
		0.05	0.1	0.2	0.05	0.1	0.2	0.2
	Months	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Magnesium oxide	1	92	90	89	88	90	93	92
	2	92	92	93	91	90	87	84
	3	90	90	90	85	87	92	17
	4	88	93	94	86	84	83	78
	5	96	93	95	76	84	83	75
	6	95	95	90	82	83	84	68
	7	96	98	90	79	89	82	66
	8	97	93	93	80	81	77	66
	9	96	93	91	78	81	77	68
	10	96	93	94	78	81	77	71
	11	97	97	97	86	86	87	--
	12	97	97	97	86	86	87	--
DDT, 3 percent in pyrophyllite	1	91	91	90	--	--	93	89
	2	95	88	90	--	--	84	74
	3	93	90	90	--	--	89	78
	4	86	90	95	--	--	90	78
	5	89	92	95	--	--	89	65
	6	96	94	95	--	--	90	67
	7	93	93	91	--	--	90	64
	8	96	96	95	--	--	88	63
	9	97	94	96	--	--	86	60
	10	97	94	96	--	--	86	59
	11	98	94	96	--	--	--	--
	12	98	94	96	--	--	--	--
		(No dust of any concentration applied)						
Check	1		87			88		91
	2		86			82		86
	3		93			87		70
	4		87			75		62
	5		94			71		51
	6		93			65		41
	7		93			64		38
	8		93			60		31
	9		95			65		--
	10		94			65		--
	11		94			68		--
	12		94			68		--

Cold Storage of Seed

As insects are inactive below 50° F., seed stored at temperatures between 40° and 50° will escape insect damage. Low moisture content in seed is important. Mites may damage seeds at 40° to 50° if their moisture content is over 12 percent. Also, fungi may develop and injure seeds even at low temperatures if the humidity approaches 80 percent. Seeds of onion, sweet corn, celery, watermelon, and pepper, stored at 80 percent humidity and a temperature of 50° showed considerable loss of viability after 6 to 9 months.

Precautions must be taken with seeds that have been kept in cold storage. If seeds of high moisture content are removed from cold storage and are then subjected to high summer temperatures, they deteriorate so rapidly that in a few weeks the benefits from cold storage may be lost. Unless seeds are to be used at once after removal from storage, determine the moisture content, and if it is above the safe limit for the temperature, dry the seeds carefully to a safe moisture content.

Use of Heat

Insects in seed may be destroyed by high temperatures. A temperature of 140° F. for 10 minutes is fatal to all stored-seed insects exposed to it. Such a temperature is not likely to injure germination, unless the seed is low in vigor or high in moisture content. New-harvested seed with a natural high moisture content should not be subjected to high temperatures until the moisture is reduced. Any method of applying heat that provides uniform heating throughout the seed is satisfactory.

Aerosols and Space Sprays

Seeds in warehouses are susceptible to infestation by moths, particularly during warm weather. Spraying with pyrethrum space sprays or aerosols every 2 weeks during warm weather is useful in preventing moth damage.

Aerosol formula:

12.5	percent pyrethrins-piperonyl butoxide (1 - 10 concentrate)
37.5	percent deodorized kerosene
50	percent tetrachloroethylene

Apply with an aerosol generator at the rate of 1½ gallons per 50,000 cubic feet.

Several types of pyrethrum space sprays are commercially available. Use as recommended by the manufacturer.

Insect-Resistant Bags

Most insects that infest seed have comparatively weak mouth parts and cannot cut through substantial wrappers. Many can thrust their ovipositors through the meshes of fabric bags and lay their eggs directly among the seed within the bags. The immature stages can crawl through the meshes and through needle holes along the seams where the bags are sewn. Closely woven fabrics offer some resistance to penetration. Bags made of paper, paper laminated to cloth, or back-filled fabrics are more resistant to insect penetration than ordinary cotton or jute bags.

Bags can be treated with synergized pyrethrum or DDT to increase their resistance to insect penetration. Treated bags can be obtained from bag manufacturers at slightly higher cost.

Summary

High moisture content and high temperature speed up the life processes of seed and unduly shorten the period of viability. These conditions also favor the rapid development of insect pests. To preserve seed and protect it from insect attack during storage, keep it cool and dry.

Seed may become infested by insects in the field, However, most infestation results from storage in bins that have not been thoroughly cleaned or that are near sources of infestation. Prompt harvest, followed by drying if necessary, and storage in clean, insect-free, weather-proof premises is essential. Bins and warehouses should be thoroughly cleaned and sprayed with a residual spray before being used. DDT, TDE, methoxychlor, pyrethrum, or allethrin all make effective sprays.

Fumigation with the common grain fumigants destroys insects, and no material damage to germination need be feared with many of them if seed moisture is not over 12 percent, exposure periods are not longer than 24 hours, the seed is aerated immediately thereafter, and dosages are not excessive.

Silica dusts, magnesium oxide, pyrethrum dusts, and DDT mixed with seed afford effective and lasting protection from insect attack under appropriate conditions. Seed treated with DDT dusts should not be used as food for man or livestock. Pyrethrum sprays are also effective in protecting seed.

Storage of seed at temperatures of below 60° F. will prevent serious insect injury, and heating of dry seed to 140° F. for 10 minutes destroys insect infestations.

Moth infestation in warehouses can be controlled by periodic application of pyrethrum space sprays or aerosols. Insect resistant bags give worthwhile protection from infestation.

PREVIOUS ISSUES OF THIS SERIES RELATED TO STORED-PRODUCT INSECTS

AMS-4.	Fumigation of dry beans and cowpeas on the packaging line. January 1955.
AMS-5.	Procedure for the fumigation of dry beans and cowpeas on the packaging line. January 1955.
AMS-49.	Timing of sprays to control the cigarette beetle. May 1955.
AMS-58.	An insect preventive program for peanut warehouses. June 1955.